Human Spaceflight Capabilities

An Integrated Low-Volume Nutritional Countermeasure to Maintain Muscle Mass and Function During Space Exploration

Completed Technology Project (2009 - 2013)

Project Introduction

Mechanical unloading, an inherent characteristic of spaceflight, results in a loss of muscle mass and muscle strength. These losses threaten the integrity of space missions and crew health upon return to Earth's gravity. Nutrition-based countermeasures represent one of the few viable intervention strategies available during long-duration spaceflight. We added leucine (0.06 g / kg lean mass / meal-1; LEU) to the regular meals served 3 • d-1 to middle-aged adults (45-60 y, representative of long-duration crew members) during 14 d of horizontal bed rest (BR) and 7 d of rehabilitation. Changes in muscle mass were assessed by dual-energy X-ray absorptiometry (DEXA); strength was evaluated with standard isokinetic dynamometry. Stable isotope tracer methodology was used to quantify muscle protein synthesis pre-BR, post-BR, and post-rehabilitation. Ongoing analysis of muscle samples for measures of protein metabolism and cell signaling continues to be batched. All subjects have tolerated the supplement (leucine or placebo) well, with no complaints. Primary findings were: 1) leucine attenuated the loss of whole body lean mass during the first 7 d of BR compared to control subjects (LEU: -0.6±0.2 kg vs. CON: -1.1±0.2 kg, $p<0.05$) and reduced or prevented decrements in knee extensor strength (LEU: -8±3% vs. CON: -15±3%, $p<0.05$), ankle extensor strength (LEU: -13±5% vs. CON: -20±5%, $p<0.05$), and knee extensor endurance (LEU: -2±4% vs. CON: -14±3%, $p<0.05$) during 14 d BR; 2) LEU maintained both post-absorptive and post-prandial MPS during BR; in contrast, BR decreased post-absorptive MPS (pre-BR: 0.061% / h-1 vs. post-BR: 0.043% / h-1, $p<0.05$); 3) insulin area under the curve during an oral glucose tolerance test was unchanged in LEU after BR (21±8%) but elevated in CON (52±23%, $p<0.05$) and whole body insulin sensitivity in LEU was significantly increased above pre-BR values after 7 d rehabilitation (17±10% vs. CON: -9±9%, $p<0.05$).

Anticipated Benefits

Our long-term goal is to identify, prevent, and remedy defects in the metabolic pathway that contribute to the loss of muscle mass and function during exposure to microgravity. Protein catabolism and muscle loss occurs in many circumstances. The regulatory mechanisms controlling protein turnover are particularly sensitive to a reduction in the neuromuscular stimulus that occurs during physical inactivity or exposure to microgravity and it is clear that muscle loss is greatly exaggerated with increasing age. Demographic data indicate that the average age of shuttle crew members has increased from 40.7 yrs in 1995 to 46.7 yrs in 2007 with an increasing number of astronauts over 50 yrs of age. We contend that the loss of muscle mass and function during spaceflight is facilitated by an age-associated, progressive impairment in the ability to mount an anabolic response to standard mixed nutrient meals. Protein supplementation is routinely employed to combat inactivity and age-related muscle loss. However, aggressive supplementation regimens are often impractical or ineffective due to issues including increased satiety, poor

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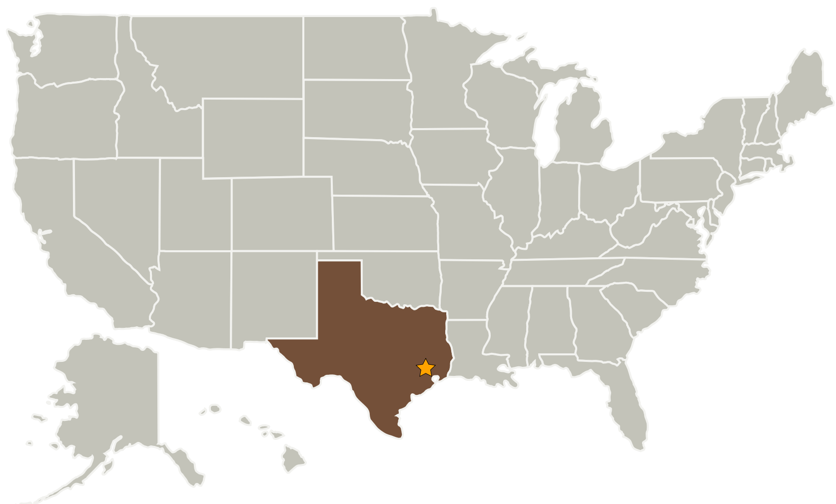
palatability, cost, and compliance. Enriching daily meals with a low-volume leucine supplement reduced some of the deleterious effects of inactivity on skeletal muscle. This supplement has the potential to also benefit individuals whose ability to perform physical activity is compromised (e.g., hospitalized patients, frail elders).

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
The University of Texas Medical Branch at Galveston(UTMD-Galv.)	Supporting Organization	Academia	Galveston, Texas

Primary U.S. Work Locations
Texas

Project Transitions

July 2009: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

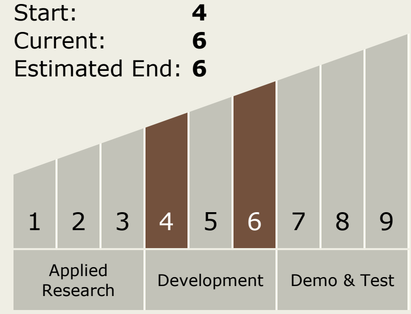
Douglas Paddon-jones

Co-Investigators:

Randall Urban
Melinda Sheffield-moore
Elizabeth Protas
Blake Rasmussen

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



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June 2013: Closed out

Closeout Summary: Mechanical unloading, an inherent characteristic of spaceflight, results in a loss of muscle mass and muscle strength. These losses threaten the integrity of space missions and crew health upon return to Earth's gravity. Nutrition-based countermeasures represent one of the few viable intervention strategies available during long-duration spaceflight. We added leucine (0.06 g • kg lean mass • meal-1; LEU) to the regular meals served 3 • d-1 to middle-aged adults (45-60 y, representative of long-duration crew members) during 14 d of horizontal bed rest (BR) and 7 d of rehabilitation. Changes in muscle mass were assessed by dual-energy X-ray absorptiometry (DEXA); strength was evaluated with standard isokinetic dynamometry. Stable isotope tracer methodology was used to quantify muscle protein synthesis pre-BR, post-BR, and post-rehabilitation. Ongoing analysis of muscle samples for measures of protein metabolism and cell signaling continues to be batched. All subjects have tolerated the supplement (leucine or placebo) well, with no complaints. Primary findings were: 1) leucine attenuated the loss of whole body lean mass during the first 7 d of BR compared to control subjects (LEU: -0.6±0.2 kg vs. CON: -1.1±0.2 kg, p<0.05) and reduced or prevented decrements in knee extensor strength (LEU: -8±3% vs. CON: -15±3%, p<0.05), ankle extensor strength (LEU: -13±5% vs. CON: -20±5%, p<0.05), and knee extensor endurance (LEU: -2±4% vs. CON: -14±3%, p<0.05) during 14 d BR; 2) LEU maintained both post-absorptive and post-prandial MPS during BR; in contrast, BR decreased post-absorptive MPS (pre-BR: 0.061% • h-1 vs. post-BR: 0.043% • h-1, p<0.05); 3) insulin area under the curve during an oral glucose tolerance test was unchanged in LEU after BR (21±8%) but elevated in CON (52±23%, p<0.05) and whole body insulin sensitivity in LEU was significantly increased above pre-BR values after 7 d rehabilitation (17±10% vs. CON: -9±9%, p<0.05).

Stories

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/34947)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/25721)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/34944)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/25733)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/8652)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/34946)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/26203)

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.3 Human Health and Performance
    - └ TX06.3.2 Prevention and Countermeasures

Target Destinations

The Moon, Mars

Awards
(https://techport.nasa.gov/file/25671)

Awards
(https://techport.nasa.gov/file/8649)

Awards
(https://techport.nasa.gov/file/24954)

Awards
(https://techport.nasa.gov/file/25443)

Awards
(https://techport.nasa.gov/file/8650)

Awards
(https://techport.nasa.gov/file/8651)

Project Website:

https://taskbook.nasaprs.com